Quantifying the variability of cloud and synoptic properties over the ARM Northeast Atlantic Azores site

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Cloud variability over the NEA

Objective:

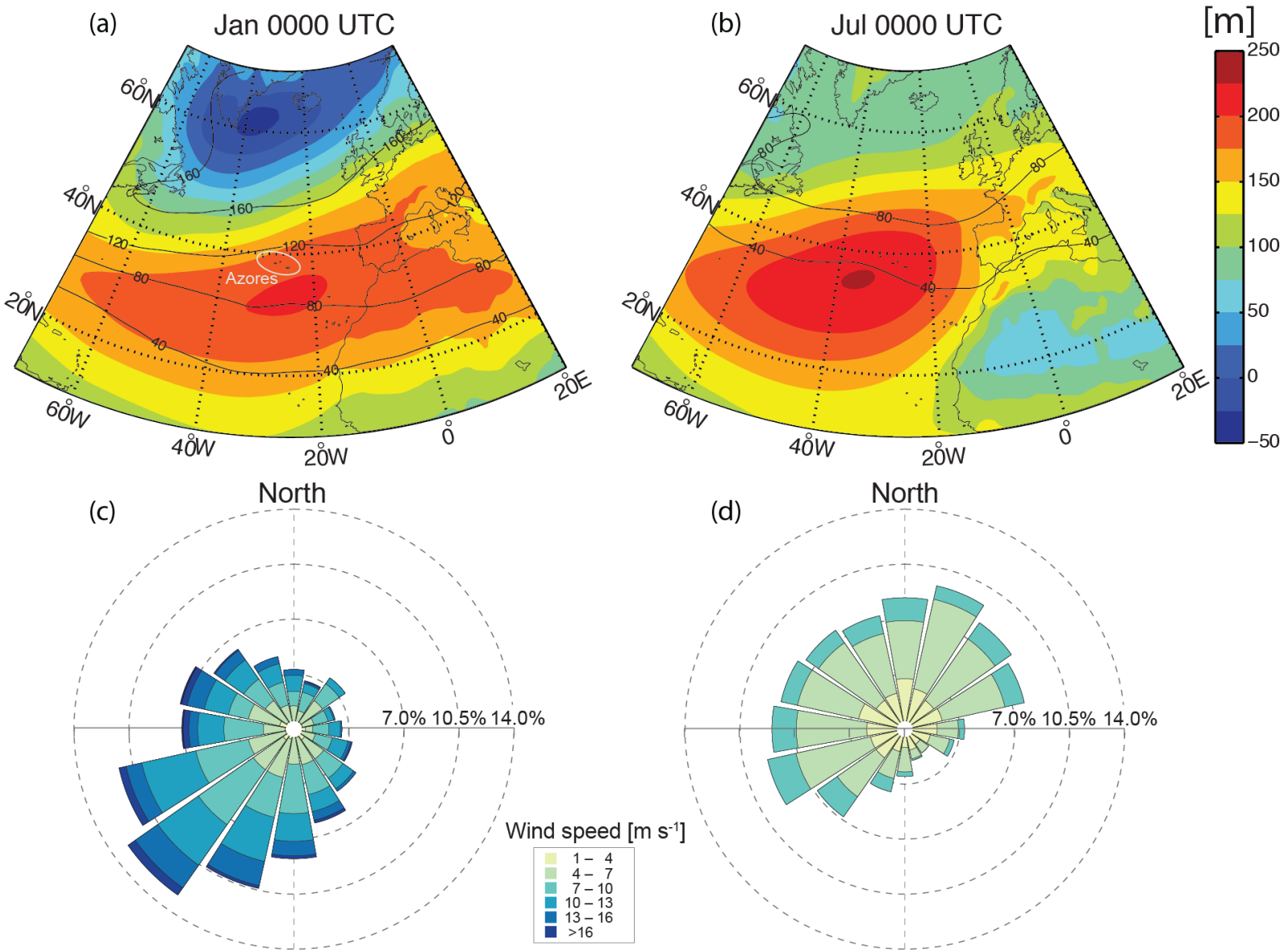
Characterize the (joint) variability in NEA synoptic and cloud properties and dependence on time of year

Motivation:

- Azores is located in a transition region
- Region of substantial gradients in synoptic and cloud properties
- Punctuated by frequent synoptic intrusions

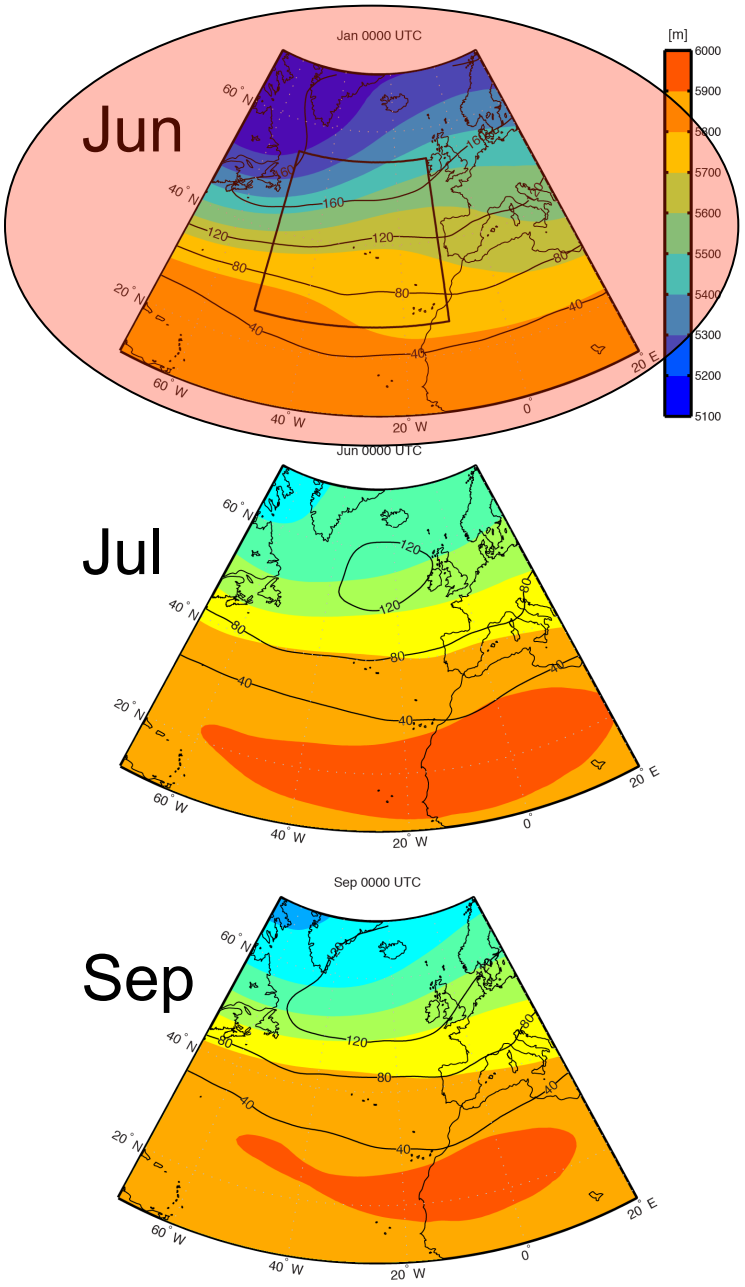
North Atlantic variability

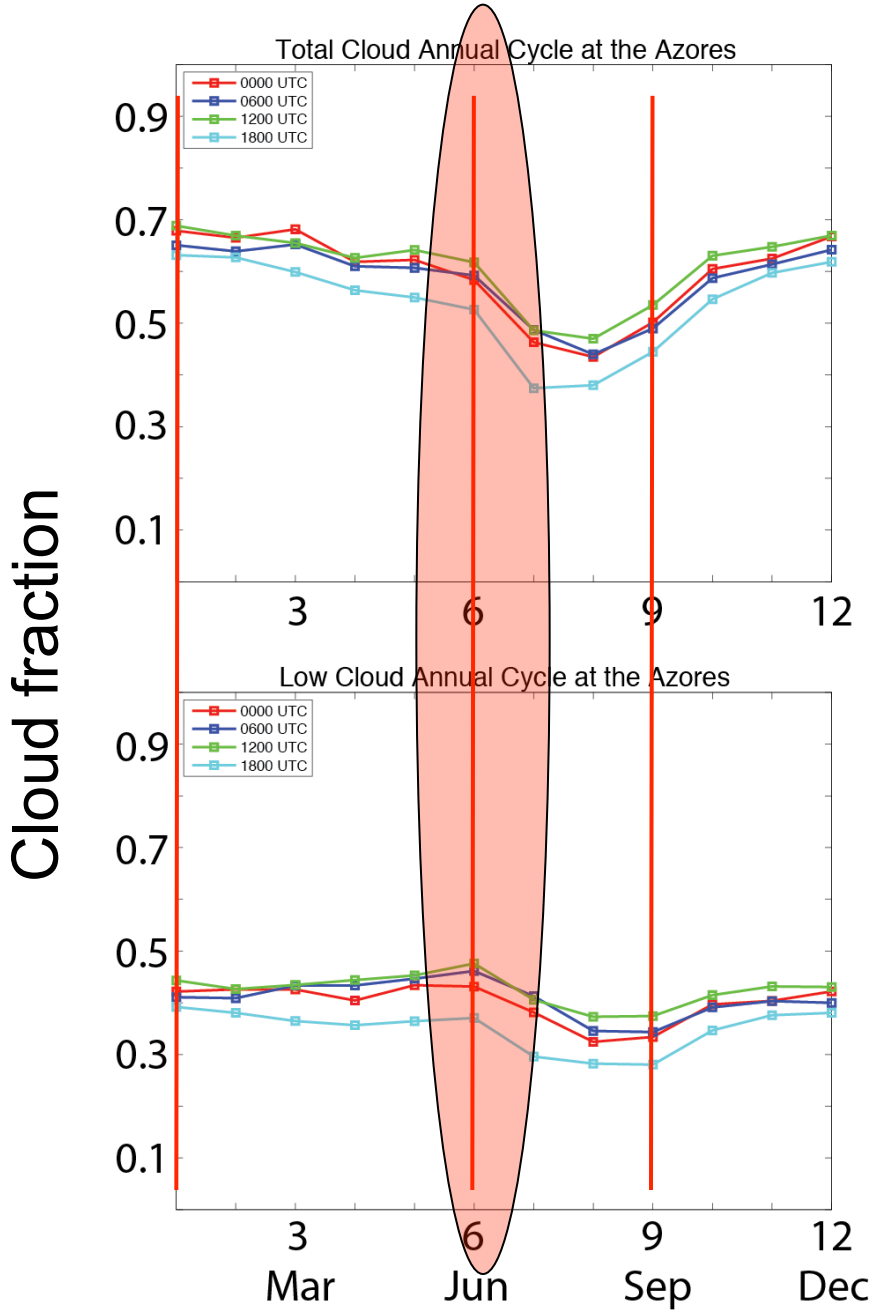
1000-hPa heights



Wood et al. (BAMS 2013, in review)

North Atlantic variability





Self-organizing map (SOM) approach

- Neural-network clustering approach that classifies the data into a user-defined number of states
- SOM analysis is based on 0000 UTC, 500-mb geopotential height anomalies that have been normalized by variance and latitude
- Results in a “codebook” (mapping) where each node is a characteristic synoptic state and each observation/data sample is associated with a specific node
- Any quantity (CF, LWP, LTS) can then be “projected” onto this node-space.

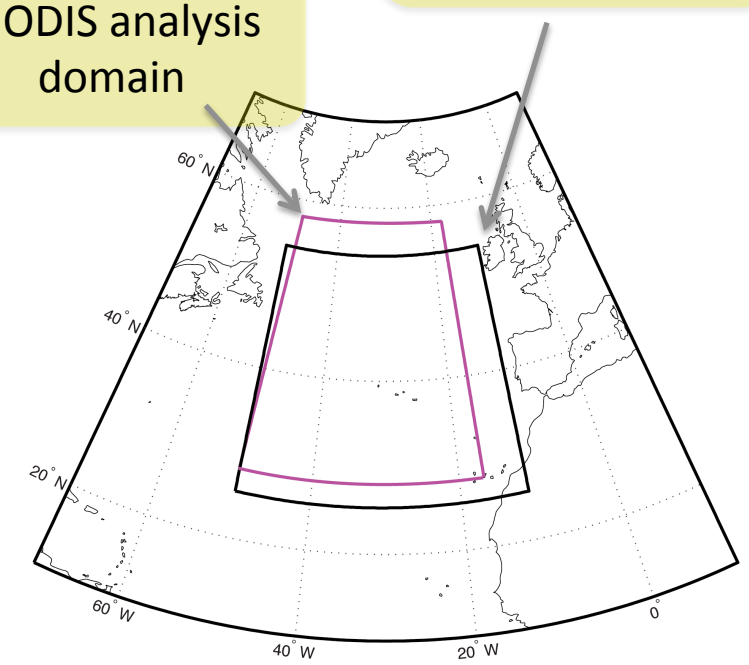
Table 1: Data Sources employed in the analysis. CAP–MBL quantities are obtained from the instruments in the text.

ERA–Interim	CAP-MBL	MODIS
geopotential height	temperature	total cloud fraction
vertical velocity	water vapor mixing ratio	liquid cloud fraction
cloud fraction	liquid water path	ice cloud fraction
temperature	cloud base and top	mixed cloud fraction
mixing ratio		unknown cloud fraction
liquid water/ice content		
sea surface temperature		
surface pressure		

25°N to 55°N
–50°W to –10°W
0.7° × 0.7° grid box

Other variables will be "projected" to assess the cloud and atmospheric properties in the region

MODIS analysis domain



Maximum-Random Overlap assumption (Geleyn and Hollingsworth 1979) applied for total cloud fraction from ERA–Interim cloud fraction:

$$C_{maxran} = 1 - (1 - C_1) \times \prod_{i=2}^{N} \frac{1 - \max(C_{i-1}, C_i)}{1 - C_{i-1}}$$

Measures of stability

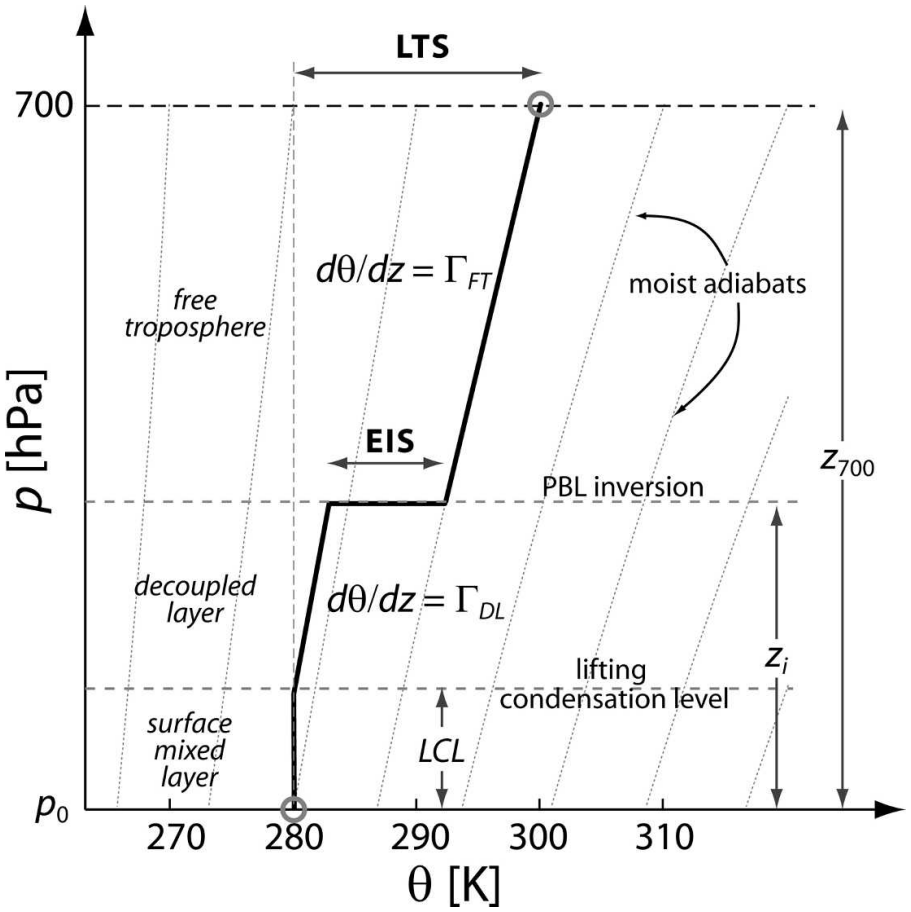
- Strong relationship between low clouds and stability
- Stability measures

Lower tropospheric stability (Klein and Hartmann 1993)

$$LTS = \theta_{700} - \theta_{surface}$$

Estimated inversion strength (Wood and Bretherton 2006)

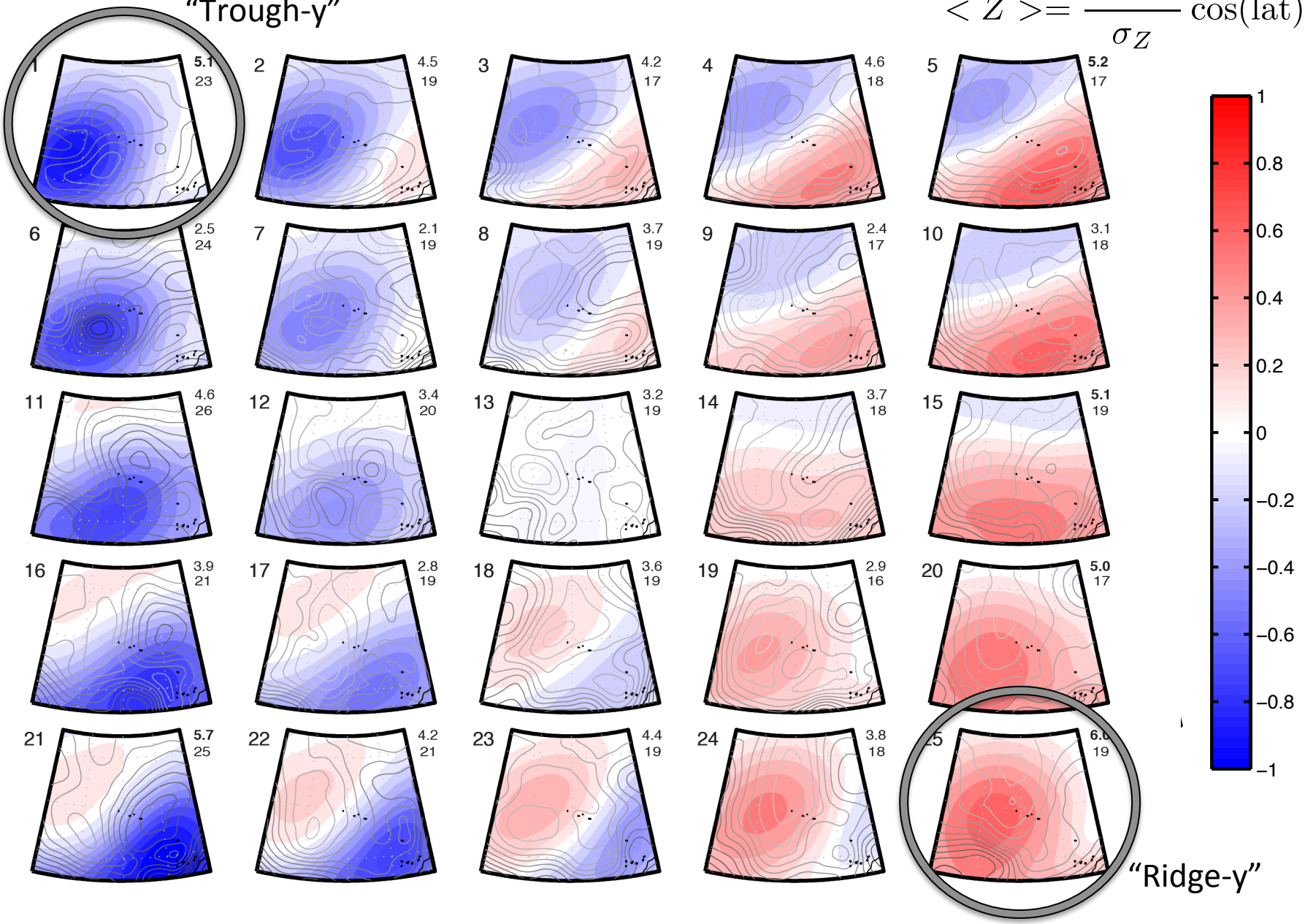
$$EIS = LTS - \Gamma_m^{850}(z_{700} - LCL)$$



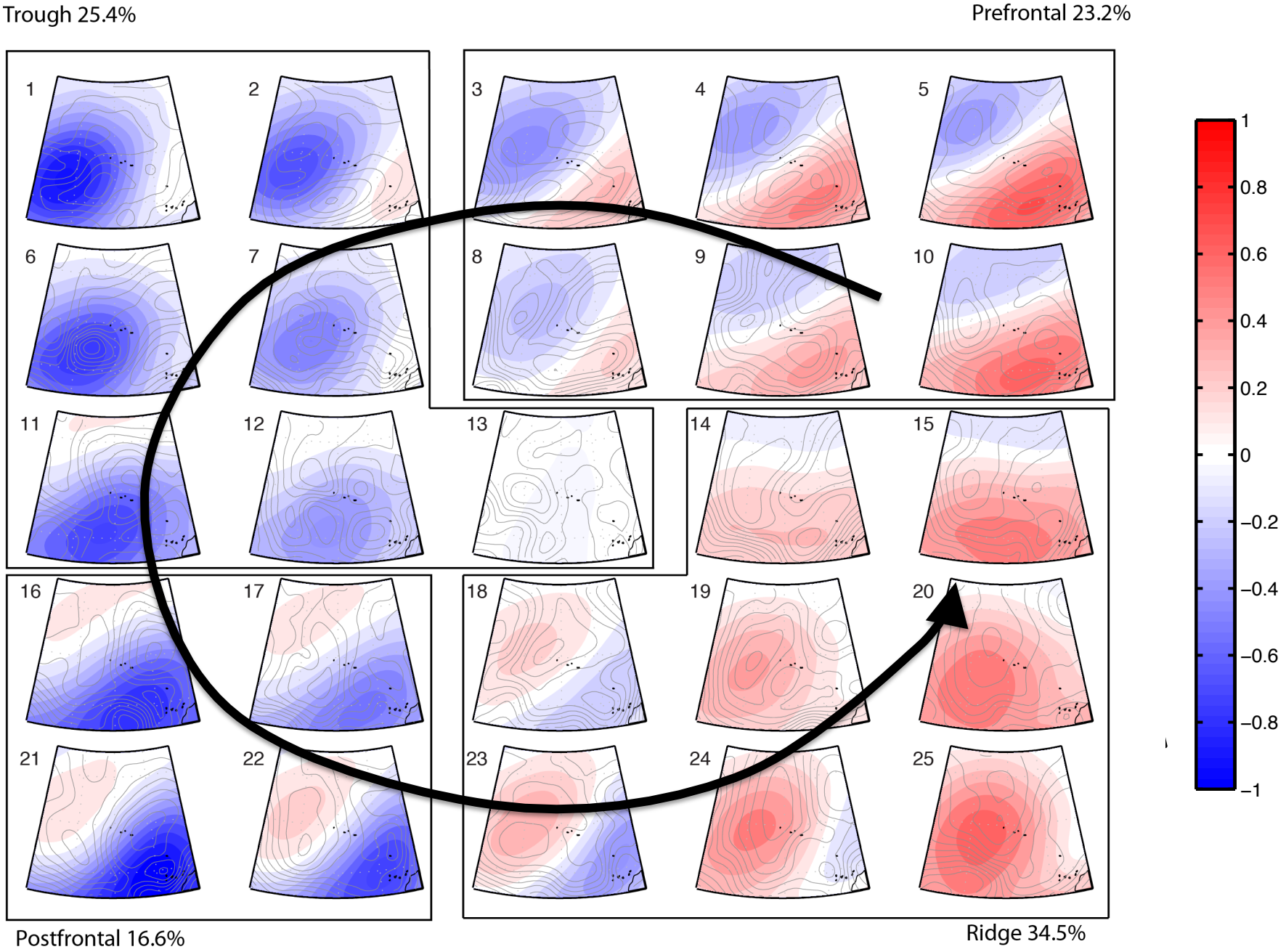
Wood and Bretherton 2006

SOM nodes — 500 mb normalized anomalies (June)

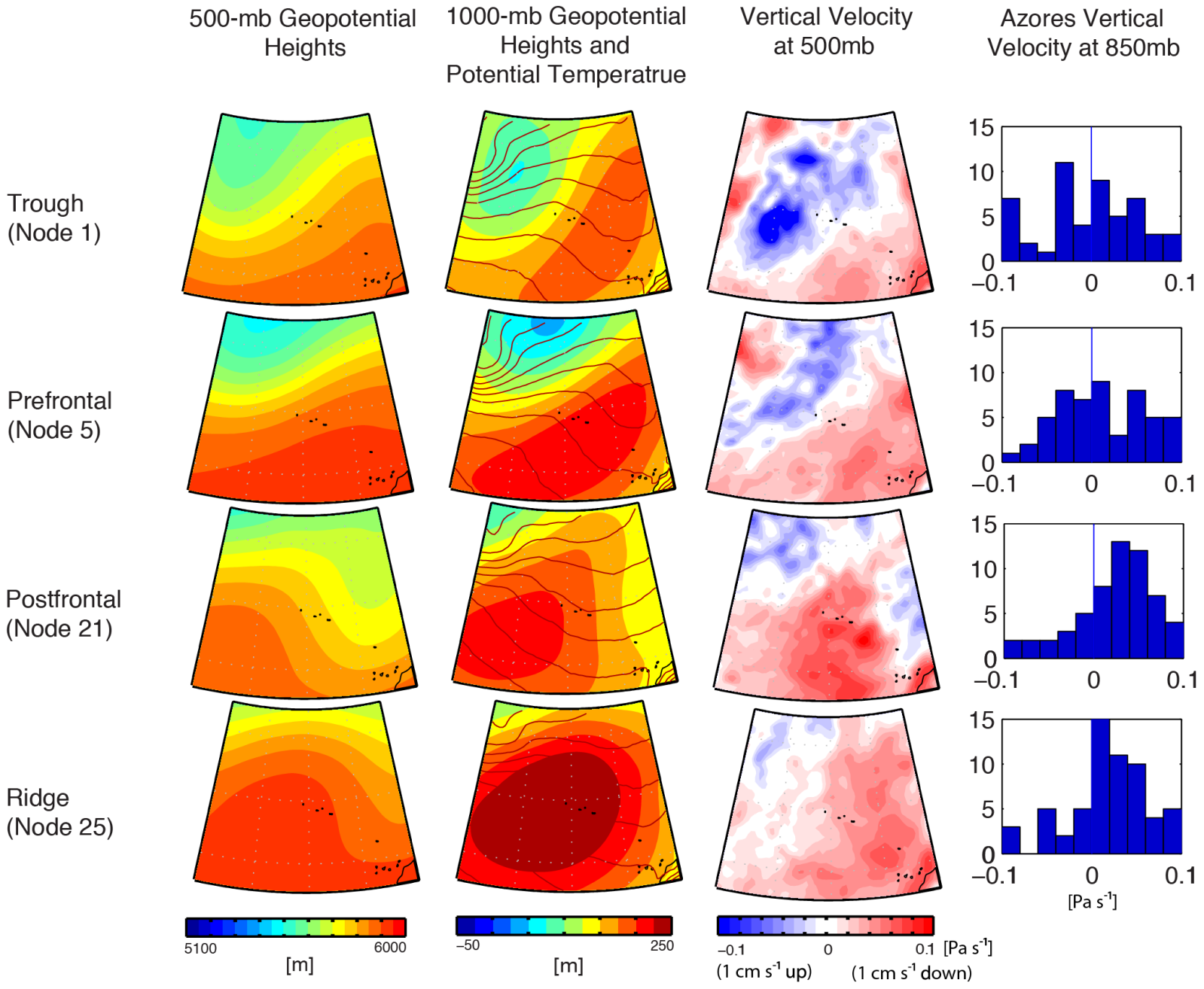
$$< Z >= \frac{Z - \bar{Z}}{\sigma_Z} \cos(\text{lat})$$



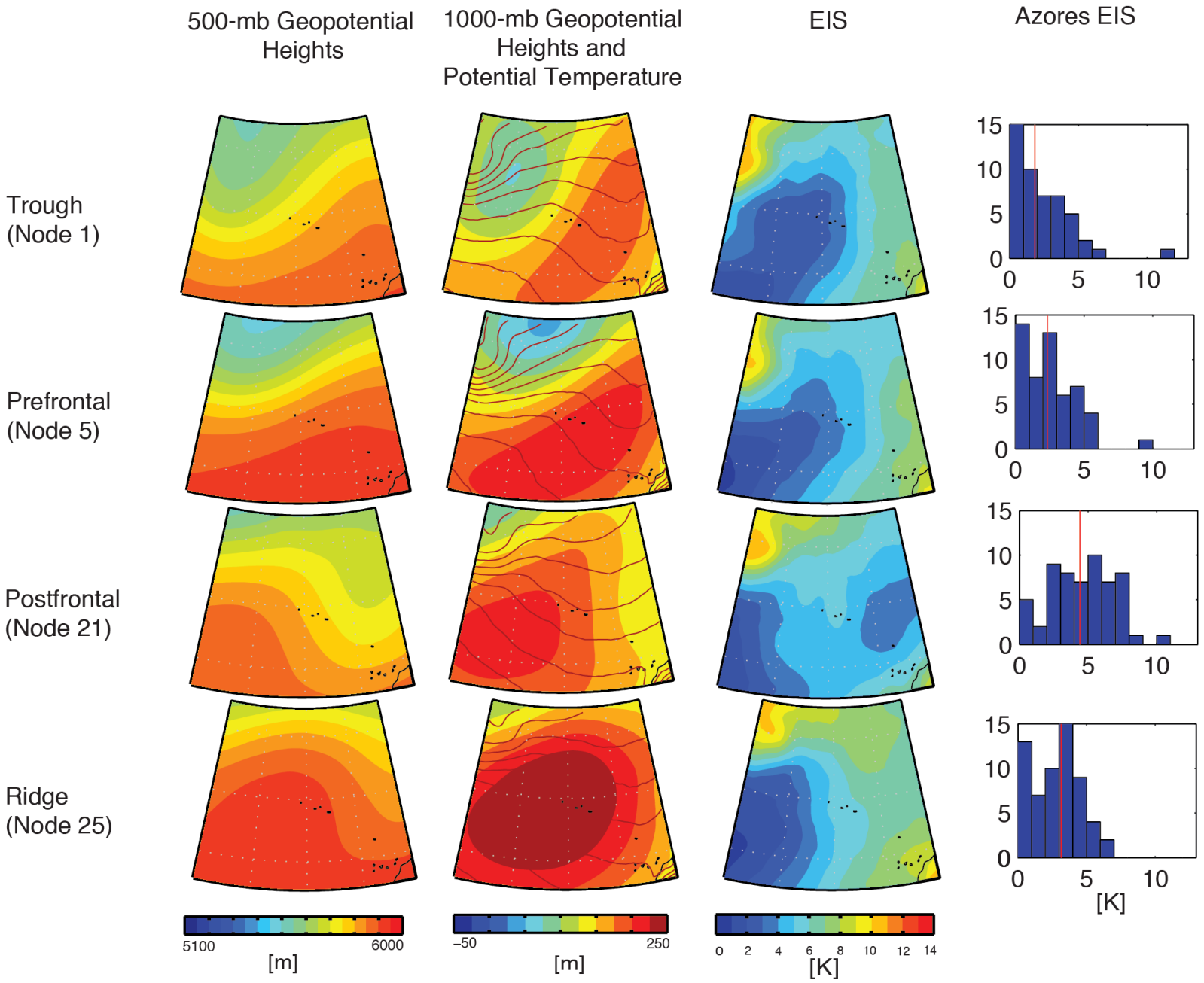
SOM nodes — 500 mb normalized anomalies (June)



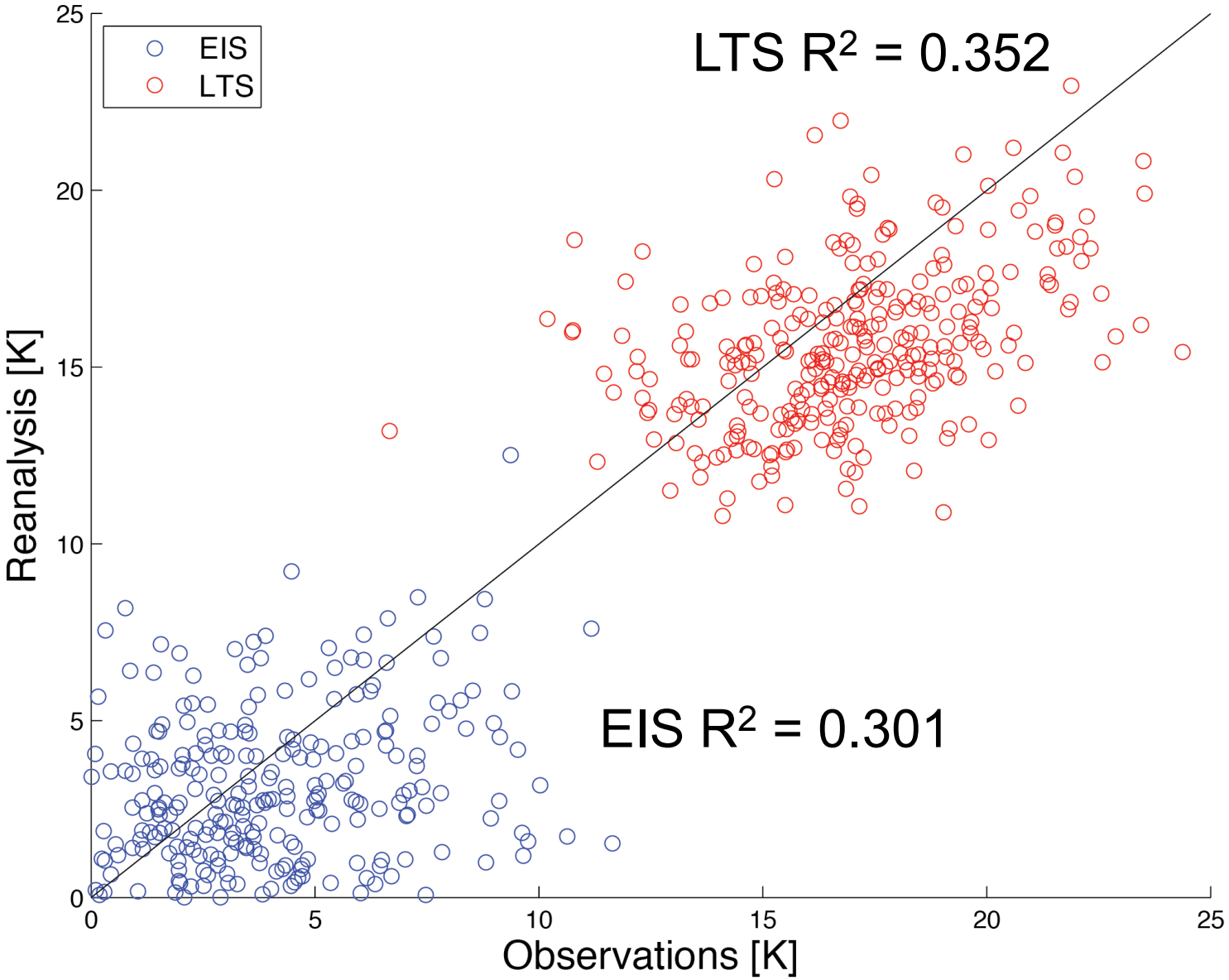
Synoptic variables projected onto SOM nodes



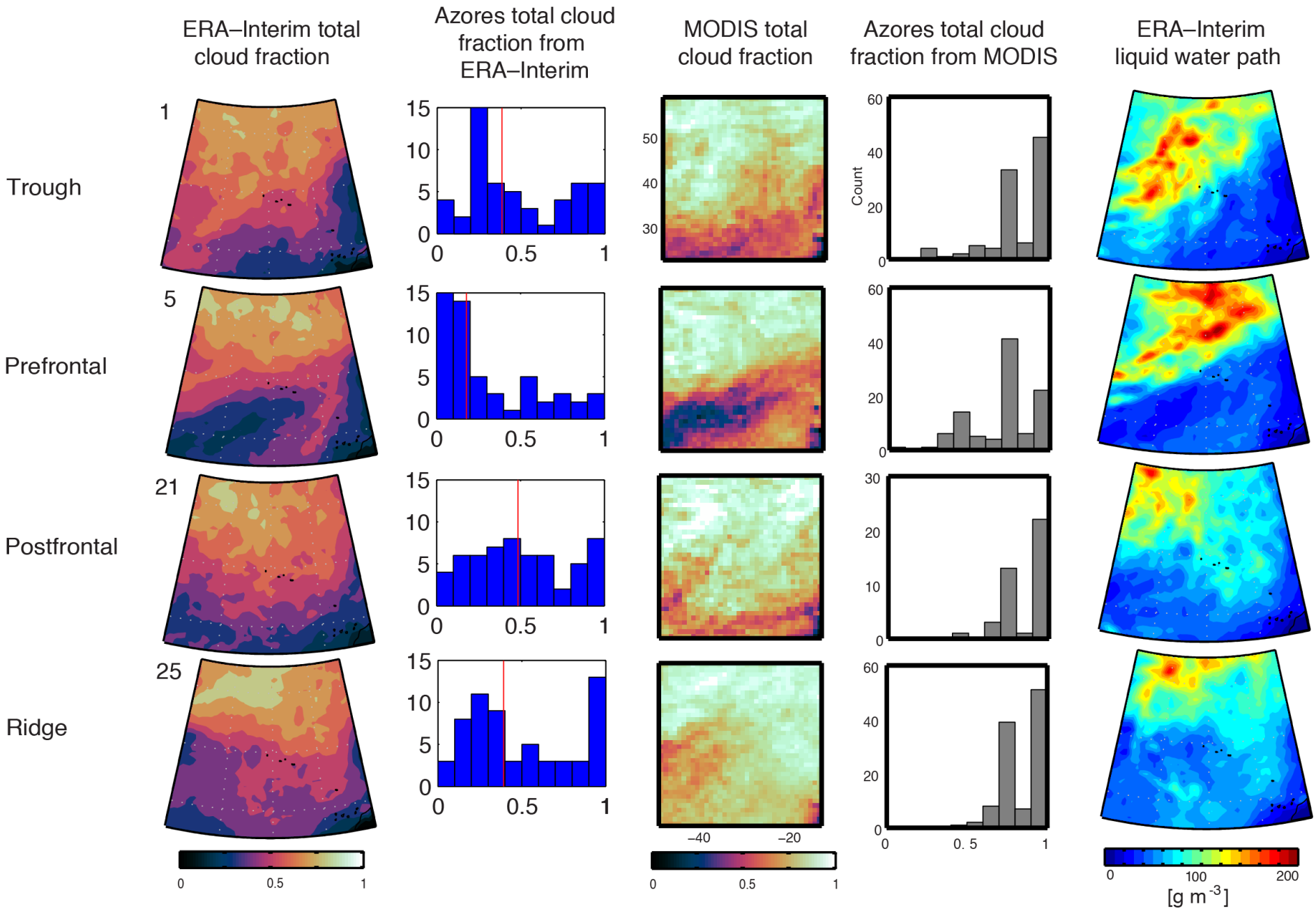
Synoptic variables projected onto SOM nodes



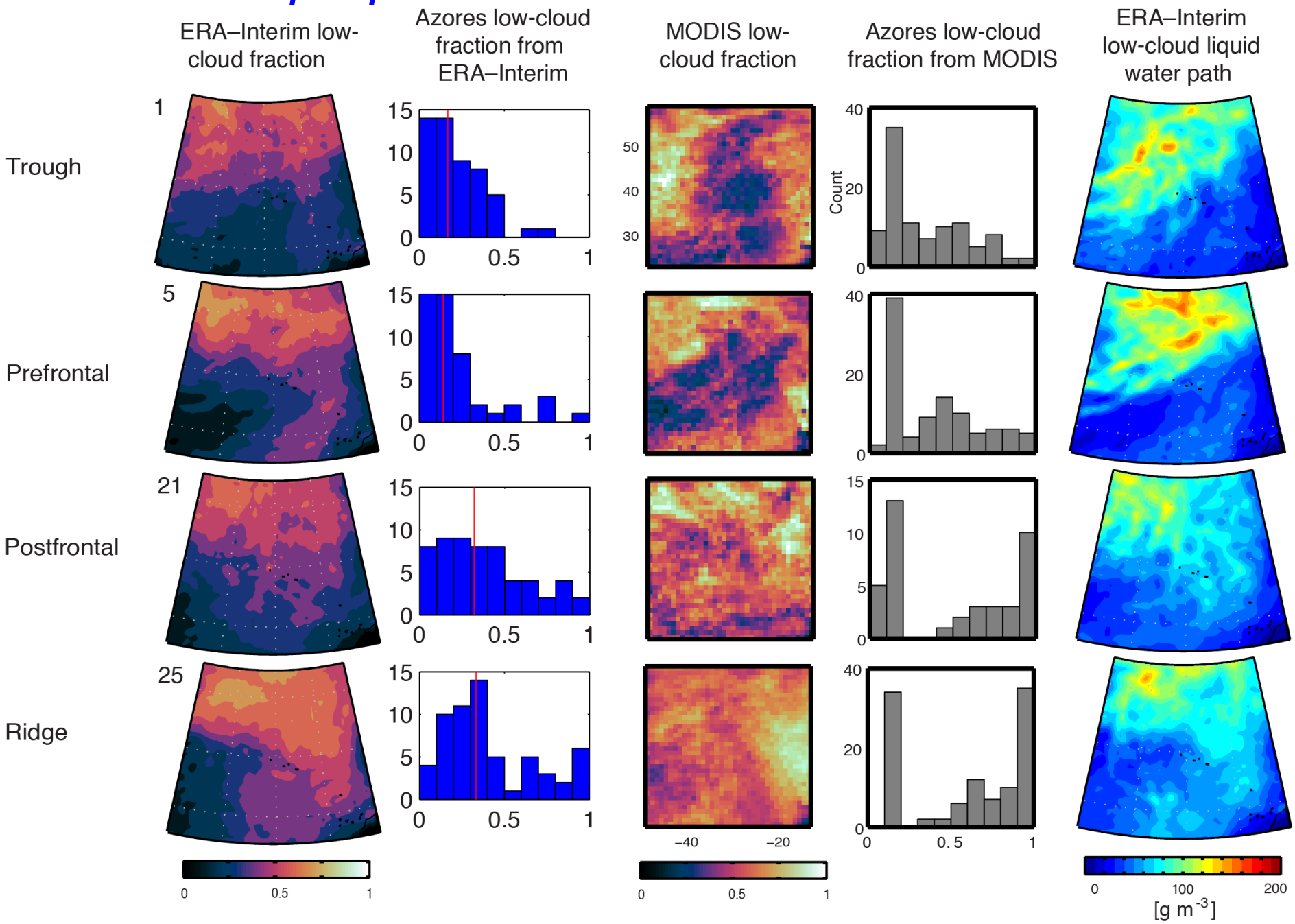
ERA–Interim vs. sounding stability



(Total) cloud properties associated with the four states



Low cloud properties associated with the four states



Preliminary conclusions

- The Azores lie in a region of substantial spatial gradients in meteorological and cloud properties.
- The SOM approach is able to identify the flow regimes associated regular synoptic intrusions from higher latitudes.
- Ridge-like conditions at 500 hPa are present ~51% of the time during June.
- Total cloud fraction in June is almost always >0.5. In the ridge regime, this is from low clouds; in the trough, the contribution is from mid- or upper-level clouds.
- Discrepancies between ERA-Interim and obs:
  MODIS cloud does not agree with ERA-interim cloud
  Stability from GRW soundings does not agree with ERA-Interim stability